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INJURY TO CASUARINA TREES IN SOUTHERN FLORIDA BY THE MANGROVE BORER

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INTRODUCTION

In southern Florida many thousand casuarina, or "Australian pine," trees (*Casuarina equisetifolia* Forster) have been and are being planted for shade and ornament along roads and avenues, on reclaimed swamp land, on golf courses, along the seashore, and as windbreaks for fruit trees (Pl. 18, A). The tree makes a rapid growth, is not affected by salt spray from the ocean, and is utilized for the same purposes as eucalyptus trees in California. It is indigenous to tropical Asia and Australasia and, in addition to southern peninsular Florida and the Florida Keys, it has been introduced throughout the West Indies and other tropical regions of North and South America.

Reports of serious injury to casuarina trees in Florida by a bark- and wood-boring insect (*Chrysobothris tranquebarica Gmelin*) [1] led to special investigations by the writer which resulted in the discovery that this buprestid beetle was a common and destructive enemy of the red mangrove (*Rhizophora mangle* Linnaeus), and that, therefore, the mangrove was the source of the trouble affecting the casuarina trees.

The fact that this beetle has so changed its normal habits as to attack and breed in a plant so different botanically from its common host, together with the economic importance of this changed habit to property owners who have made extensive plantings of the casuarina, has rendered the subject of special scientific interest and practical importance.

The first reports of insect injury to the casuarina came from Hobe Sound and Miami Beach in April, 1916. These and other localities in southern Florida were visited by the writer in May, 1916, March and April, 1917, and April and May, 1918, in order that a thorough investigation of the insect, the conditions relating to its attack, and the methods of combating it might be made.

[1] Determination by Mr. W. S. Fisher, Bureau of Entomology.

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CHARACTER AND EXTENT OF THE INJURY

It was found that the mangrove borer attacks only living red mangrove and casuarina. The casuarina trees attacked range from 2 to 6 inches in diameter; those over 5 years old usually are not attacked, except high in the tops or branches. Small casuarina trees are attacked near the base as a rule. In case of small trees the trunk may be girdled before the larvæ attain their growth, and in most cases the damage is done before the presence of the insect is noticed. Many casuarina trees were killed at Miami Beach in 1915 (Pl. 18, B) and more in 1916. The infestation in 1917 at Miami Beach was apparently less than in 1916, it having been estimated that among trees planted during the winter of 1916–17, within half a mile of the mangrove swamp, not more than 1 tree out of 20 was lost.

In the mangrove swamp along Biscayne Bay many red mangrove trees were found in 1916 to have been killed by the borer. In 1917 a great accumulation of dead and stag-headed mangrove trees which had been gradually killed by the borer was noted, and many newly infested trees. In 1918 many additional mangrove trees were found infested and it was noted that the infestation extended for many miles north of Miami. The dead trees and the stag-headed, partially killed trees, many of which are of large size, are strikingly evident against the sky line.

At Hobe Sound, Jupiter Island, Fla., which is farther north than Miami Beach, quite a few casuarina trees were killed in 1915; the trees are nearly 5 years old and, hence, not so liable to attack. At this locality the red mangrove is low and scrubby, being apparently too far north for favorable growth. In the swamps near by the borer was found in the red mangrove, but the infestation was not heavy.

On the ocean keys or reefs south of Miami the red mangrove apparently is not infested by *C. tranquebarica*. At Adam Key, about 27 miles south of Miami, neither the red mangroves nor the casuarinas which have been planted there are infested, and no damage to mangrove by the borer has been noticed. On Key Biscayne, just south of Miami, there was formerly a heavy infestation in the casuarinas, but the trees have now reached an age at which they are out of danger of further attack. Infested red mangroves apparently do not occur in swamps continuously from Miami Beach to Hobe Sound; therefore there are broken centers of infestation. No infested trees have been found south of Key Biscayne.

STAGES, HABITS, AND SEASONAL HISTORY OF THE BEETLE

Although *C. tranquebarica* was collected by Mr. H. K. Morrison at Key West in 1886 and by Mr. E. A. Schwarz on cordwood of red mangrove at the same locality in 1887 and although the beetle has been known to science since 1787, it appears that nothing has been recorded regarding its various stages, seasonal history, habits, etc.

Because of its thorough establishment in the red mangrove it is evident that this beetle was not introduced into Florida with the casuarina; in fact, specimens had been collected at Key West before the casuarina was planted in Florida.

The beetle's habitat is the West Indies, where the red mangrove tree is also native.

In India the casuarina is a common tree, but the red mangrove does not occur. *C. tranquebarica*, despite its specific name,[1] does not occur in India. Tranquebar is on the east coast of Madras.

THE ADULT

The adult of the mangrove borer (Pl. 20, D; 21) is metallic greenish bronze and has two lighter-colored and one smaller basal impressions on each elytron. There are also impressions on the thorax. Adults can be told from those of any other species of Chrysobothris found in the United States by the fact that the eyes are nearly contiguous on top of the head. The female is larger than the male, and the front of the head is green. The length ranges from 13.5 to 17 mm. The smaller, more active male ranges in length from 12.5 to 14 mm.; the front of the head is bright red. There are other sex differences in the last ventral segment of the abdomen (Pl. 19, A) and, of course, in the genitalia.

Adults of both sexes are fond of bright sunlight and are commonly found flying from 10 a. m. to 3 p. m. (central time) in open places in the swamps and on the casuarina trees. Oviposition takes place in either morning or afternoon.

Both male and female beetles feed on the tender, succulent bark of the trees which they infest. They may be found resting on the trunks of trees in the bright sunlight chewing through the outer bark to the cambium.

The beetles, owing to their rapidity of movement, strong powers of flight, and shyness, are probably able to survive enemies and live for two or three weeks, or possibly a month or so. They are difficult of detection when resting on the bark of red mangrove, but when flying in the sunlight they are conspicuous on account of the bright-green color of the body. The beetles are never active unless the day is warm, sunny, and not windy.

As the beetles are strong fliers and are fond of flitting from one sunny tree trunk to another, and as they lay many eggs each, it is probable that one female may be responsible for the death of many trees.

On April 13, 1918, in a mangrove swamp along Biscayne Bay, opposite Miami, Fla., females were found ovipositing at 1.10 p. m. (central time), and the operation observed. After a short exploration of the bark, made with extended ovipositor (Pl. 19, B), a proper crevice was

[1] Fisher, W. S. Chrysobothris tranquebarica Gmel. versus impressa Fabr. *In* Proc. Ent. Soc. Wash., v. 20, no. 8, pp. 173-177. November, 1918 (1919).

found under loose bark and the beetle remained with its ovipositor in the crevice for one and one-half minutes. During this time there was a perceptible pumping motion near the basal end of the ovipositor, and 4 eggs were laid in an irregular row. The tree is attacked anywhere from the large aerial roots to high up on the trunk, but usually in the middle trunk.

THE EGG

The egg (Pl. 19, C) may be compared in shape to a scallop shell, and one end, which is broader than the other and flattened, is irregularly ribbed. It is white and ranges from 1 to 1.5 mm. in length; the average width is approximately 0.75 mm.

The red mangrove has the bark separated into plates; in the process of growth loose bark occurs at the dividing lines (Pl. 19, C). The eggs are inserted under this thin outer layer of loose bark in an irregular longitudinal row. Four eggs are the largest number that have been found together. Eggs occur singly and in twos and threes. One female may lay eggs in several trees. Twenty-three full-sized eggs were dissected from one female, many eggs being in the distended oviduct, and many immature ovules were present.

The period of incubation was not determined but probably one week is required. Young larvæ 5.5 mm. in length were found on April 23, 1918, in a red mangrove tree near Miami Beach.

THE LARVA

The larva[1] is white and a typical "flatheaded" borer (Pl. 20, B; fig. 1). It is of the common Chrysobothris type, moderately compressed, and sparsely covered with coarse, light-colored bristles. The first thoracic segment is large and oval; the second wider and shorter than the third; the third wider than the first abdominal, which is narrower than the second abdominal; the third to eighth abdominal are of about equal width, the ninth and tenth successively narrower; the lateral folds of the second to ninth abdominal segments are well developed; the dorsal plate of the first thoracic segment is marked with a well developed, inverted V of grooves and pointlike rugosities; the ventral plate has a well developed groove extending back three-fourths of the distance from the anterior margin, and rugosities which tend to form ridges. The length is 30 mm. and the width of the first thoracic segment 7 to 8 mm.

The young larvæ upon hatching from the eggs bore through the cambium to the surface of the wood and as they feed on the cambium and grow they extend the burrows horizontally, spirally, or longitudinally (Pl. 20, A). The entire length of the burrow is packed with boring dust. The length of the larval period is nearly one year. When

[1] Description by Mr. H. E. Burke, Bureau of Entomology.

full grown or mature, the larva ranges from 29 to 35 mm. in length. At this stage it bores into the wood to a considerable depth and excavates its pupal cell. A hole for the exit of the beetle is also excavated by the larva from the pupal cell to or near to the surface and is there

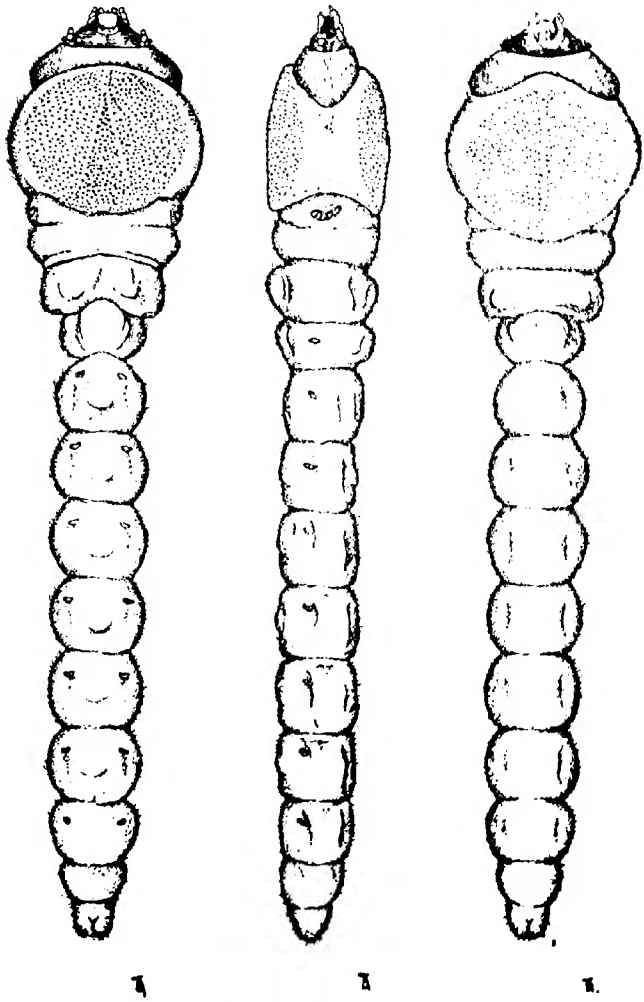


FIG. 1.—*Chrysobothris tranquebarica*: Larva, dorsal, lateral, and ventral views. × 5.

finally packed with coarse boring chips. In some large, heavily infested red mangrove trees as many as three pupal cells per linear 2 inches were found.

THE PUPA

The pupa is white and of the shape characteristic of buprestid pupæ (Pl. 20, C; fig. 2). It is of the common Chrysobothris type, with the head resting on the breast and the legs and wings folded on the ventral surface. The developing insect gradually acquires characters of the adult beetle. The size varies with the individual and there is also a sex difference; the length ranges from 15 to 20 mm.

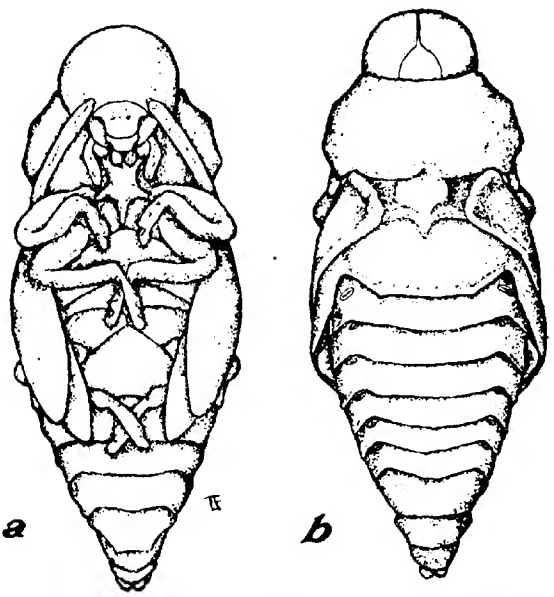


FIG. 2.—*Chrysobothris tranquebarica*: *a*, Female pupa, ventral view; *b*, same, dorsal view.

The average duration of the pupal period is about two weeks. When the adult becomes mature it chews its way out through the plug of wood fiber, cuts an oval hole through the bark, and escapes. This hole is often mistaken by property owners for the point of entrance of the borer.

SEASONAL HISTORY

One year is required for the development of the mangrove borer from egg to adult. Adult beetles first begin to emerge about the 1st of April. The period of maximum activity of the beetles on the wing is from the

middle of April to the 1st of June, but a few stragglers are found as late as August. Most of the eggs are probably laid from the middle of April to June. The larvæ seem to be full grown by August, and the majority form the pupal cells before winter. The species probably passes through a dormant period, or one of comparative inactivity, during the months of December, January, and February, as mature larvæ under the bark or in the pupal cells. On March 19, 1917, such mature larvæ, together with pupæ and immature adults, were found in infested trees at Miami Beach. On April 4, 1917, many pupæ were changing color, indicating that they would soon transform to the adult stage. In 1918, on April 8, mature larvæ, pupæ, and adults were in pupal cells in infested trees at Miami Beach. The first eggs were found on April 13, 1918, and the first young larvæ on April 23, at Miami Beach, in infested red mangrove trees.

PREDATORY ENEMIES AND PARASITES

The flicker (*Colaptes auratus*) and the red-headed woodpecker (*Melanerpes erythrocephalus*) pick out larvæ and pupæ from infested trees, and often obtain a high percentage of the insects infesting a few trees. Predacious beetle larvæ account for other borers. On April 3, 1917, larvæ of a predacious trogositid beetle (*Tenebroides* sp.)[1] were found under the bark of a red mangrove tree infested by *C. tranquebarica*, in a swamp near Miami Beach.

On April 9, 1918, in the same general locality, larvæ of an elaterid beetle (*Adelocera* sp.)[2] were found under the bark of a red mangrove tree infested with the beetle. Presumably they were predacious enemies of the mangrove borer.

Two species of hymenopterous parasites have been found. One species, *Atanycolus rugoventris* Ashmead,[3] was found to be fairly common at Miami Beach in 1917 and 1918. Its cocoons occur in a mass at the end of the larval burrow of the beetle. Adults were found emerging from the cocoons on March 19 and April 10, 1917, and on April 9, 1918. The other species, *A. labena* n. sp.,[3] constructs a single cocoon in the pupal cell of *C. tranquebarica*, in infested casuarina trees.

Notwithstanding the numerous natural enemies of *Chrysobothris tranquebarica* it is evident that reliance can not be placed upon them to control this borer without help from man.

CONTROL OF THE BORER

In view of the large number of casuarina trees which have been and are being planted in southern Florida and the varied uses to which they are adapted, it will be seen that the problem of controlling this injurious borer is important. Since 1916 owners of these large plantations have

[1] Determination by Dr. Adam G. Böving, Bureau of Entomology.
[2] Determination by Mr. J. A. Hyslop, Bureau of Entomology.
[3] Determination by Mr. S. A. Rohwer, Bureau of Entomology.

been acting upon the advice of the Bureau of Entomology in efforts to prevent injury, but the problem is greatly complicated at Miami Beach by large areas of heavily infested red mangrove trees in near-by swamps.

In 1916 and 1917, at Miami Beach, badly infested young casuarina trees were removed or topped, and borers were killed in the pupal cells by cutting them out. Some trees were sprayed with poisoned kerosene emulsion. Supporting stakes of red mangrove were removed. In 1917 the infestation appeared to have been reduced, but in 1918 it was again severe. In the red mangrove swamps there appeared to be a steady yearly increase of infestation.

The infestation at Hobe Sound, the farthest north that *C. tranquebarica* has yet been found, has not been so severe. The casuarina trees are now (May, 1918) about 5 years old and of large size. In May, 1916, when these trees were younger and the injury more severe, the trunks were thoroughly and repeatedly sprayed with the poisoned kerosene emulsion. About 900 casuarina trees growing in avenues were sprayed at a cost of approximately 10 cents per tree. As the old formula, used at this time, contains a larger proportion of sodium arsenate than is necessary, the cost per tree can be lowered. The outfit consisted of three men and a team of mules to haul the standard orange-tree spray pump. Almost any good spraying outfit, however, would answer the purpose of spraying the trunks of small trees.

In addition to spraying, the rough bark at the bases of trees at Hobe Sound was scraped and the borers killed by cutting them out of the pupal cells. The infestation of 1916 was less and there was a still further decrease in that of 1917, after the use of the same control methods. A few borers were still found in the tops of the casuarina trees in 1918 but these have been cut out. The infestation in the low scrubby red mangrove tree here is not and has not been heavy.

METHODS RECOMMENDED FOR COMBATING THE INSECT

Investigations have shown that many trees can be saved by carrying out the following methods of control: All badly damaged casuarina trees should be cut and burned between September and March to kill the insects before they emerge. The trees may be entirely removed, cut off near the ground, or merely topped so that they will sprout from the stump and make new growth. Since the borer usually attacks the young trees near the base, where there are rougher bark and more suitable places for egg laying, care should be exercised that no infested stumps remain. Trees only slightly damaged and showing evidence, in the rapidly healing wounds, of recovery should not be cut. The wounds will soon heal, and as the trees grow will disappear.

Casuarina trees between 1½ and 6 inches in diameter, growing in proximity to mangrove swamps or near other infested casuarina trees, should be examined carefully in September and March and the young larvæ

killed by spraying the affected part of the trunks with poisoned kerosene emulsion [1] made in accordance with the following formula, recently revised by Mr. F. C. Craighead:

Standard miscible oil	pint	1
Water	gallons	5
Sodium arsenate	pound	¼

Dissolve the arsenate in water, stir, then add 1 pint of miscible oil.

From April to June, when large numbers of the adult beetles are flying and feeding on the bark, they should be killed by spraying the tree trunks with the poisoned kerosene emulsion.

No pruning of casuarina trees should be attempted between April and August, since the consequent flow of sap will attract the flying beetles to the trees.

Mangrove stakes should not be used to support young, recently set-out trees, as they will attract the borers.

According to the host-selection principle [2] as advocated by Dr. A. D. Hopkins, the beetles that breed for one or two generations or more in the casuarina will be much more likely to reinfest this host than they are to go back to the original host; and, since the beetle became established in the mangrove before the casuarina was introduced, it is to be expected that only occasional individuals, among the thousands of beetles that breed in the mangrove, will deposit eggs on the casuarinas. It is of primary importance, therefore, to keep as many of the beetles as possible from reaching maturity in the casuarinas.

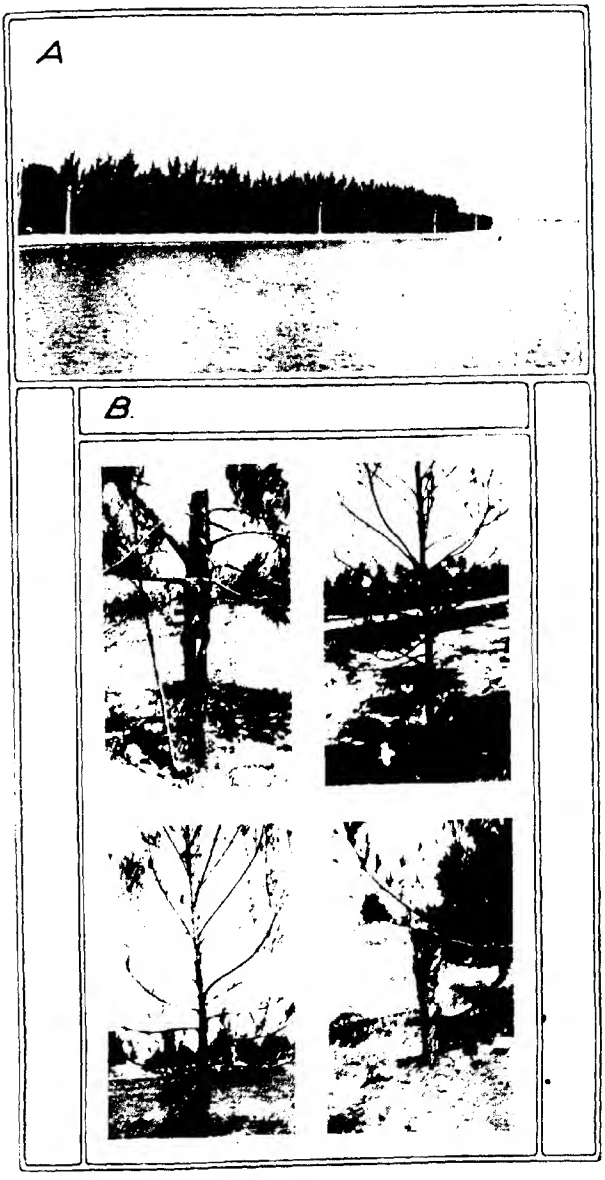
[1] CRAIGHEAD, F. C. A NEW MIXTURE FOR CONTROLLING WOOD-BORING INSECTS. SODIUM ARSENATE EMULSION. *In* Jour. Econ. Ent., v. 8, no. 6, p. 513–516. 1915.

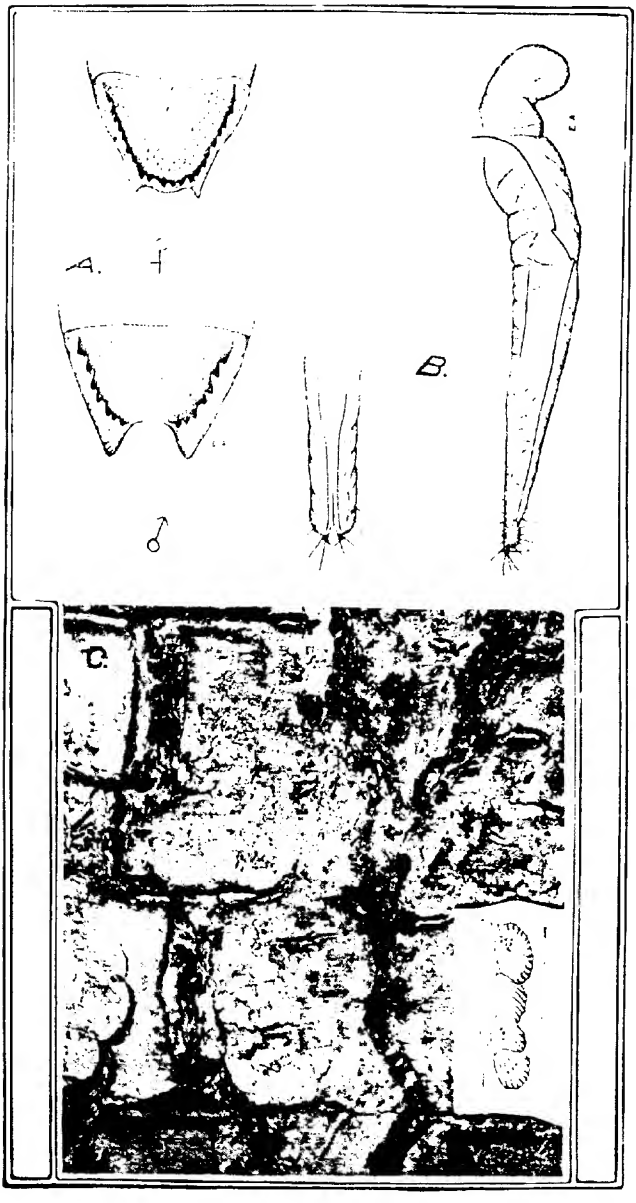
[2] U. S. DEPARTMENT OF AGRICULTURE. PROGRAM OF WORK [1918]/1919, p. 161. Washington. 1916.

PLATE 18

A.—Casuarina trees planted along the water front. Belle Isle, Miami Beach, Fla., June, 1918. Photographed by W. E. Brown.

B.—Casuarina trees disfigured and killed by the mangrove borer (*Chrysobothris tranquebarica*) at Miami Beach, Fla.


A
B.


A.
♂
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C.

PLATE 19

Chrysobothris tranquebarica

A.—Sex differences in the last abdominal segment. × 9.
Drawn by E. Armstrong.

B.—Lateral and dorsal view of ovipositor. × 9
Drawn by E. Armstrong.

C.—Bark of red mangrove (*Rhizophora mangle*) showing how it is divided into plates. Natural size. The eggs are superficially inserted under the thin outer layer, where the bark is loose, at a crack. Eggs × 4.

PLATE 20

Chrysobothris tranquebarica

A.—Larval burrow in cambium of Australian pine (*Casuarina equisetifolia*), Miami Beach, Fla. Note how the burrow is packed with frass, the exit hole and the cambium growing over the wound. Natural size.

B.—Larvae, ventral and dorsal views. × 3.

C.—Pupa, dorsal and ventral views. × 2½.

D.—Female and male adult beetles. × 2½. Photographed by Mr. William Middleton.

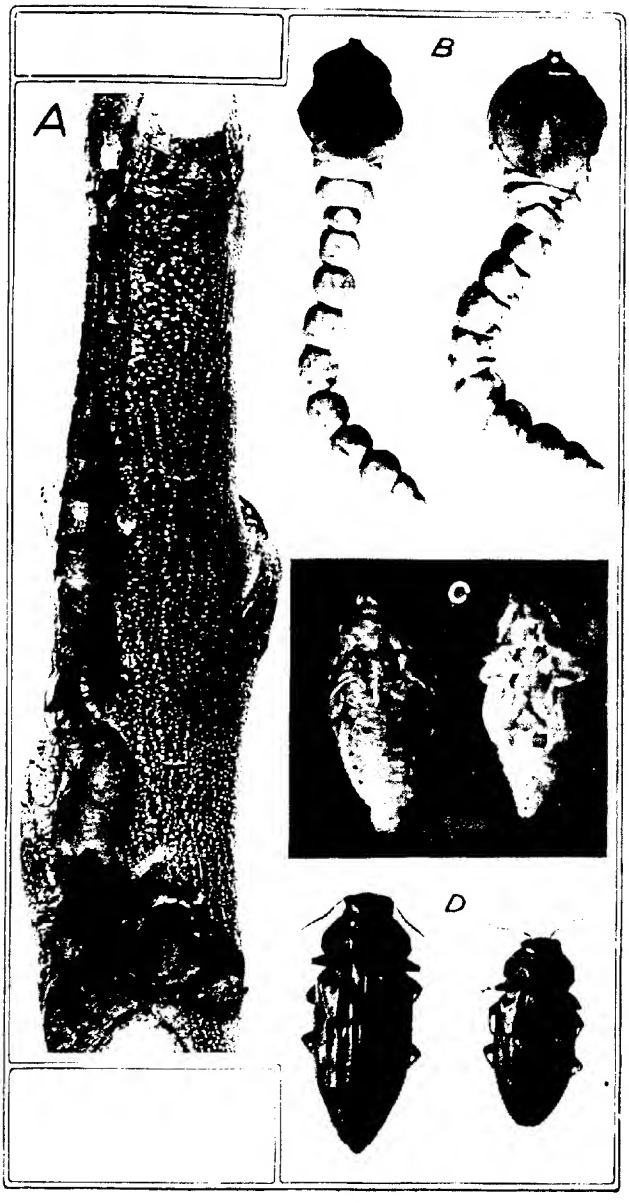
A
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PLATE 21

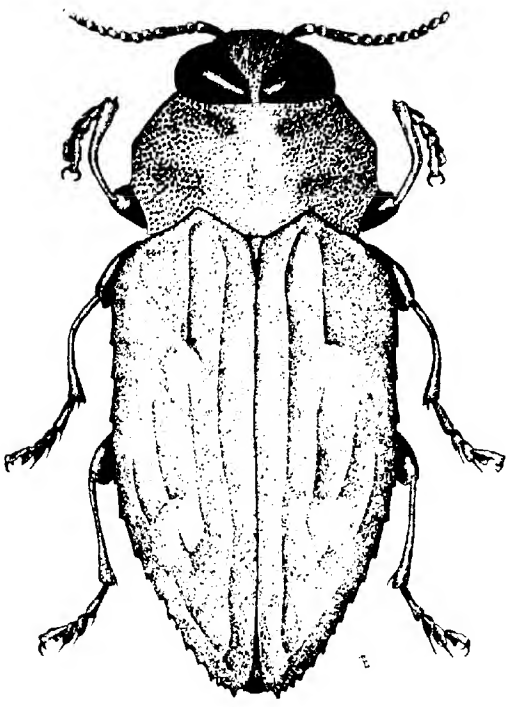

PLATE 21

Chrysobothris tranquebarica:

Adult male, dorsal view. × 7.

LIFE-HISTORY OBSERVATIONS ON FOUR RECENTLY DESCRIBED PARASITES OF BRUCHOPHAGUS FUNEBRIS

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INTRODUCTION

The parasitic Hymenoptera referred to in this paper were observed, together with others, while the writer was making a detailed study of the chalcis-fly *Bruchophagus funebris* infesting the seeds of alfalfa (*Medicago sativa*) and red clover (*Trifolium pratense*).

Observations and notes were made concerning the life habits of these new parasites, as the opportunity presented itself, to determine any economic value which one or more of these species may have in the control of *Bruchophagus funebris*.

LIFE-HISTORY SUMMARY OF THE HOST

The host insect, *Bruchophagus funebris* Howard, completes its development from the egg to the adult stage within the seed of alfalfa, red clover, or wild species of Medicago. Upon reaching maturity the adult gnaws an opening through the seed shell and makes its escape. *B. funebris* hibernates in its larva stage within the infested seeds remaining upon the field. It passes through several generations in a single season.

METHOD OF STUDYING THE PARASITES

In order that the development of these parasites could be observed, it became necessary to dissect several thousand alfalfa seeds under the microscope, locate parasite larvæ, and remove them together with their host for study. Each host, with its parasite, was then transferred to a single little cage consisting of an 8-mm. cork with a small cavity in one end and covered by a medical capsule. Here each parasite could be observed from day to day until it had completely destroyed its host, developed, passed through the pupa stage, and transformed to the adult stage.

LIODONTOMERUS PERPLEXUS GAHAN

The two species of Liodontomerus discussed in this paper belong to the hymenopterous superfamily Chalcidoidea, family Callimomidae, and subfamily Monodontomerinae. The genus Liodontomerus was erected by Mr. A. B. Gahan,[1] of the Bureau of Entomology, for specimens of *Liodon-*

[1] GAHAN, A. B. DESCRIPTIONS OF NEW GENERA AND SPECIES WITH NOTES OF PARASITIC HYMENOPTERA. *In* Proc. U. S. Nat. Mus., v. 48, p. 155–168, Dec. 16, 1914. p. 159: Liodontomerus, new genus

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tomerus perplexus Gahan reared by the writer from *Bruchophagus funebris* infesting alfalfa seeds at Yuma, Arizona.

Liodontomerus perplexus was first reared by the writer from alfalfa seeds collected at Yuma, Ariz., during August, 1912. It was again reared September 20, 1912, from El Centro, California, and from Chino, Cal., on November 4, 1912. Infested alfalfa seeds dissected and subjected to a microscopic examination soon showed this species as being parasitic upon *Bruchophagus funebris*. In the year 1913 it was first reared on July 19 from Corcoran, Cal.; on July 25, from Glendale, Cal.; and in 1914 the first rearing dates from new localities were July 24, Brawley, Cal., and September 8, Red Bluff, Cal. On August 4 it was reared from *B. funebris* infesting bur clover (*Medicago hispida nigra*) at Tulare, Cal.

Examinations of various chalcids reared by different members of the Bureau of Entomology from alfalfa seeds infested by *Bruchophagus funebris* showed that *Liodontomerus perplexus* was reared by C. N. Ainslie at Newell, South Dakota, November 15, 1913, and at Mitchell, S. Dak., in 1914. A single specimen was labeled "Red Oak, Iowa."

Liodontomerus perplexus was described by Mr. Gahan as a new species [1] from the type specimens reared by the writer from *Bruchophagus funebris* infesting alfalfa seeds at Yuma, Arizona, in August, 1912.

STAGES OF HOST SHOWING PARASITISM

Liodontomerus perplexus is primarily parasitic upon the larva stages of *Bruchophagus funebris*. It feeds externally upon its host and frequently destroys the entire host larva with the exception of the head. In exceptional cases this parasite has been found to be parasitic upon the pupa stage of *B. funebris*. Of 97 larvæ of *L. perplexus* under observation 86 were parasitic upon the larva stage and 9 upon the pupa stage of their host. A single specimen of this species was found to be a secondary parasite and feeding upon the larva of a different species after the latter had destroyed the host larva.

HIBERNATION

The larvæ, which become fully developed late in the summer, or in the fall, mostly hibernate until the following spring. This takes place within the alfalfa seeds in which the host was attacked. While hibernation is normal in the larva stage, occasional individuals have been observed to hibernate in the pupa stage under the mild climatic conditions of the Southwest.

APPEARANCE IN THE FIELD

This species does not seem to appear in the field in large numbers as early in the season as might be expected. In southern California and western Arizona it becomes active in April and slowly increases in numbers throughout May. In August the abundance of adults is probably greatest, while a few individuals may be found as late as November (Table I).

[1] GAHAN, A. B., OP. CIT., p. 159.

TABLE I.—*Dates of emergence of adults of Liodontomerus perplexus which developed from larvæ spending the winter in hibernation*

Date.	Number of male adults.	Number of female adults.
March 1–15		
March 16–31		
April 1–15	1	1
April 16–30	2	1
May 1–15	2	
May 16–31	3	
June 1–15	8	13
June 16–30	1	5
July 1–15	5	2
July 16–31	3	6
August 1–15	2	1
August 16–31	1	4
September 1–15		
Percentage	45.89	54.09

OVIPOSITION

The adult female locates the green and tender seed pods of alfalfa in which seeds are infested by larvæ of *Bruchophagus funebris*, inserts the ovipositor through the seed pod, and deposits an egg upon or near the host larva within the green seed.

LARVA

DEVELOPMENT.—The different larval instars were not studied by the writer through lack of time for this particular subject. Field and laboratory observations, however, showed that the larvæ develop very rapidly upon their host and under favorable conditions require from 8 to 12 days to make their growth. They do not always transform to the pupa stage as soon as they become full grown.

DORMANT PERIOD.—After the larva of *Liodontomerus perplexus* has become fully developed upon its host within the alfalfa seed it may at once enter the pupa stage, but if the seed is exposed to dry climatic conditions a dormant period in the larva stage frequently follows. This dormant period may begin at almost any time throughout the summer and continue right on into hibernation. Transformation to the pupa stage is then delayed until the following spring. In the laboratory a few larvæ that became dormant in the summer continued so throughout the following winter and through the next summer, and hibernated again the second winter before transforming to the pupa. A hibernating larva was taken from the field on December 18, 1913. It remained in the larva stage until March, 1915, then transformed to a pupa, and emerged as an adult on April 19, 1915. This particular habit is undoubtedly of great value to the species and enables it to be carried over the long continued dry seasons of the desert sections of the Southwest.

DESCRIPTION.—The larva of *Liodontomerus perplexus* (fig. 1) varies in color from white to smoky gray. The length averages 1.5 mm. and the thickness averages 0.7 mm. The general appearance is grublike, while a side view shows the general shape, suggesting an interrogation mark. The head of the larva shows the eye lobes and on each a small tubercle. The front of the head contains about eight fine setæ. Mandibles, slightly chitinous, are usually inconspicuous, but sometimes distinctly visible. Segmentation of the 13 body segments is very marked. The body is covered with bristle-like setæ which are from 0.04 mm. to 0.1 mm. in length. Two rows, and a broken third row, are present in the first segment. The second and third segments each bear one row with a broken second row. The other segments each bear one row encircling the segment. Setæ on the dorsal portion of the body are much coarser than those of the ventral side. The last segment is dorso-ventrally bilobed and bears setæ on each of the lobes.

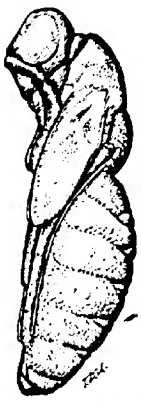


FIG. 1.—*Liodontomerus perplexus*: Larva.

PUPA

PUPATION.—After the pupa has completed its development within the larval skin the latter breaks open along the antero-dorsal margin and is slowly worked back to beyond the tip of the abdomen by a slight movement of the newly formed pupa.

DESCRIPTION.—The pupa (fig. 2) is white when newly formed. It is about 1.5 mm. long and 0.5 mm. thick. The eyes are at first white, but after a few days turn to pale brown. The head and thorax bend slightly forward. The antennæ, legs, and wing pads are folded close to the body and the ovipositor sheath is bent back across the end of the abdomen. In the last few days of the pupa stage the pupa turns almost black, with dark-brown eyes and pale-brown antennæ, legs, and ovipositor.

FIG. 2.—*Liodontomerus perplexus*: Pupa.

LENGTH OF PUPAL PERIOD.—The length of the pupal period varies greatly according to the season during which pupation occurs. Hibernating larvæ under observation began entering the pupa stage as early as March; others did not pupate until July and August, and a few remained in the larva stage until the following year before pupating. Twenty-six pupæ, which proved to be males, averaged 23.7 days in the pupa stage; and 31 pupæ, which proved to be females,

averaged 27.9 days in that stage. The longest pupal period observed was 45 days and the shortest was 8 days. These observations were made in the laboratory under natural temperatures. It is very probable that under the most favorable field conditions the pupal period may require even less time than the minimum period recorded.

ADULT

EMERGENCE.—The adult (Pl. 22, A), upon emerging from the pupal skin, finds itself surrounded by the thin seed wall and within the alfalfa seed pod. It proceeds at once to gnaw a small irregular opening through the seed in which the host has been destroyed, then through the seed pod, and thereupon escapes.

RELATIVE PROPORTION OF SEXES.—Both sexes of this species seem to be well represented in all of the localities from which specimens were reared. A count made of 859 adults showed 121 to be males and 738 females, or a ratio of 1 to 6.92.

ADULT VARIATION.—Some adults of this species vary from the true type in that they show a stigmal cloud in the forewing. In a few individuals this clouded area was very conspicuous.

SEASONAL HISTORY

Observations show that about 30 days, under very favorable conditions, are required for the complete development of a single generation and that in alfalfa seed fields of Arizona and southern California there may be as many as three generations in a single season. Other individuals subjected to different local conditions may require an entire season for their development.

PARASITIC IMPORTANCE

This species appears to be a parasite of considerable economic importance in helping to reduce the ravages of *Bruchophagus funebris* in alfalfa seed throughout the western Arizona seed-growing districts. It is apparently not present in sufficient numbers throughout the California, Idaho, and Utah seed-growing sections to be of value in reducing the destructive work of the seed chalcis-fly.

LIODONTOMERUS SECUNDUS GAHAN

Liodontomerus secundus was first collected by the writer on September 5, 1914, at Albany, Oregon, where it was found ovipositing in the green ovaries of florets on red-clover heads. On September 16 the writer reared specimens from red-clover seeds infested by *Bruchophagus funebris* at Caldwell, Idaho; and on September 23 it was reared from infested red-clover seeds taken at Albany, Oreg. Microscopic examination of the seeds showed that this species was parasitic upon the larvæ of *B. funebris*. It was also present among chalcids reared from red clover in 1915 at Elk Point, South Dakota, by C. N. Ainslie.

Liodontomerus secundus was described as new by Mr. A. B. Gahan[1] from specimens reared by the writer from infested red-clover seeds taken at Caldwell, Idaho.

HIBERNATION

Examination of red-clover seeds infested by *Bruchophagus funebris* revealed larvæ of *Liodontomerus secundus* hibernating in the larva stage within the seeds which had been destroyed by their respective host larvæ. The hibernating larvæ pupated in the months of April, May, and June, spending from 24 to 40 days in the pupa stage under laboratory conditions before emerging as adults.

FIG. 3.—*Liodontomerus secundus*: Larva.

FIG. 4.—*Liodontomerus secundus*: Pupa.

LARVA

The larva (fig. 3) is smoky white in color and averages 1.72 mm. long and 0.8 mm. in thickness. The general shape is grublike. The head, of medium size, shows the eye lobes with a tubercle apparently more distinct in this species than in *L. perplexus*. Pointed mandibles show a slight tinge of brown. The body is covered with pubescence about 0.055 long, the pubescence longest on dorsal portion of first two body segments. Pubescence finer than on larvæ of *L. perplexus*.

PUPA

The pupa (fig. 4) is white when newly formed, but later it turns smoky white and finally brownish black. The eyes turn brown. It averages 1.6 mm. long. The sheath of the ovipositor is folded around the end of the abdomen and back half way along the dorsal side.

ADULT

The adults (Pl. 23, B) emerge from the infested red-clover seeds in spring. Some continue to emerge from the old seeds as late as July. They apparently have two or more generations in a single season and are active in the fields until late in fall.

Observations show that both sexes are well represented in localities where the species was taken.

[1] GAHAN, A. B. DESCRIPTIONS OF SOME NEW PARASITIC HYMENOPTERA. *In* Proc. U. S. Nat. Mus., v. 53, p. 195–217. May 26, 1917. p. 208: *Liodontomerus secundus*, new species.

EUTELUS BRUCHOPHAGI GAHAN

Eutelus bruchophagi belongs to the superfamily Chalcidoidea, family Pteromalidae, and subfamily Pteromalinae.

This insect was first reared by the writer from alfalfa seeds infested by *Bruchophagus funebris*, collected at Blackfoot, Aberdeen, and Caldwell, Idaho, and from Nephi, Gunnison, Manti, and Salt Lake City, Utah, in September, 1914, and from Susanville, California, on September 12, 1917.

Mr. T. R. Chamberlin, of the Bureau of Entomology, reared males of this species from alfalfa seeds collected at Salt Lake City in June, 1914.

Upon careful examination of the infested seeds this species was soon found to be parasitic upon *B. funebris*.

Specimens reared by the writer at Nephi, Utah, were described by Mr. A. B. Gahan, of the Bureau of Entomology, as a new species.[1]

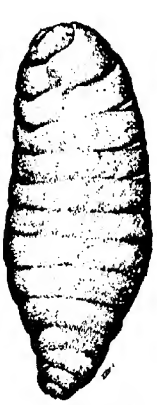


FIG. 5.—*Eutelus bruchophagi*: Larva

FIG. 6.—*Eutelus bruchophagi*: Pupa

HIBERNATION

Eutelus bruchophagi hibernates in the larva stage within the infested alfalfa seeds and seed pods remaining on the fields. The warm spring days hasten pupation, and a few weeks later the newly formed adult gnaws an opening through the seed wall and makes its escape.

LARVA

The larva (fig. 5) is grublike in appearance and averages 1.5 mm. in length. Its body is white with a glossy surface free from pubescence and having a clouded appearance under the epidermis. The head is of medium size and the eye lobes rather shallow. The setæ on the eyes are distinctly visible. The anal segment is bilobed and shows three very fine setæ.

PUPA

The pupa (fig. 6) is white when newly formed and after a few days shows the eyes turning to salmon brown. It averages 1.5 mm. in length, and turns black before changing to the adult stage.

ADULT

The adults (Pl. 22, B) live for one or two months under favorable conditions and locate, for oviposition, on the newly-forming seed pods of alfalfa

[1] GAHAN, A. B. *op. cit.*, 1917, p. 313

plants which have become infested by *Bruchophagus funebris*. Apparently there are at least two generations in a single season.

The specimens reared showed a much larger percentage of males than of females.

TIMEROMICRUS MACULATUS GAHAN

Trimeromicrus maculatus (Pl. 23, A) belongs in the hymenopterous superfamily Chalcidoidea, family Pteromalidae, and subfamily Pteromalinae. Specimens reared by the writer were determined by Mr. A. B. Gahan of the Bureau of Entomology as belonging to a new genus. The genus Trimeromicrus was therefore erected by Mr. Gahan [1] for this species.

This species was first reared by the writer from alfalfa seeds infested by *Bruchophagus funebris* and taken at Yuma, Arizona, in September, 1912. Larvæ of this species were later dissected from alfalfa seeds where they were found to be parasitic upon the larvæ of *B. funebris*. It was later reared from the following localities:

El Centro, Cal., September, 1912.
Glendale, Cal., September, 1912.
Chino, Cal., November, 1912.
Corcoran, Cal., July, 1913.
Tulare, Cal., June, 1914.
Red Bluff, Cal., September, 1914.
San Diego, Cal., August, 1915.
Susanville, Cal., September, 1917.

Examination of the undetermined collections and the field notes made by different members of the Bureau of Entomology showed that this species was also reared from infested alfalfa seeds as follows:

Mesilla Park, N. Mex., June, 1909, C. N. Ainslie.
Sacaton, Ariz., June, 1909, C. N. Ainslie.
Casa Grande, Ariz., June, 1910, V. L. Wildermuth.
Wellington, Kans., August, 1910, E. G. Kelly.
Brawley, Cal., March, 1911, V. L. Wildermuth.
Tempe, Ariz., July, 1911, E. G. Smyth.
Buckeye, Ariz., July, 1912, R. N. Wilson.
Newell, S. Dak., August, 1913, C. N. Ainslie.
Salt Lake City, Utah, September, 1915, T. R. Chamberlin.

Trimeromicrus maculatus was described as a new species by Mr. A. B. Gahan [2] from the specimens reared by the writer from *Bruchophagus funebris* infesting alfalfa seeds at Yuma, Arizona.

HIBERNATION

This species, like the others mentioned, hibernates in the larva stage within the infested alfalfa seeds. It frequently hibernates as early as September. In early spring the larvæ change to pupæ, remain so for about 30 days, and the adults emerge from the seeds by the time the new seed pods are forming.

[1] GAHAN, A. B. DESCRIPTIONS OF NEW GENERA AND SPECIES WITH NOTES OF PARASITIC HYMENOPTERA. *In* Proc. U. S. Nat. Mus., v. 48, p. 155-168. Dec. 10, 1914. p. 161: Trimeromicrus, new genus.

[2] Op. cit., 1914, p. 162.

LARVA

The larva (fig. 7) varies from white to smoky gray, averages 1.6 mm. in length, and is somewhat grublike in general shape. The head is of medium size and faintly shows the eye lobes. Each eye lobe shows a very fine seta.

The thirteen body segments are subequal, the first one back of the head being the largest and the others decreasing in size to the anal segment, which is bilobed, the upper lobe containing three very fine setæ. The dorsal portion of the first twelve body segments also shows indications of very short and fine setæ in some specimens.

PARASITIC HABIT.—The larva of this species was found to attach itself externally upon the larva of its host. In the course of a few days the host larva apparently dies and the parasite makes a rapid growth, feeding upon the body contents of the dead host.

FIG. 7.—*Trimeromicrus maculatus*: Larva

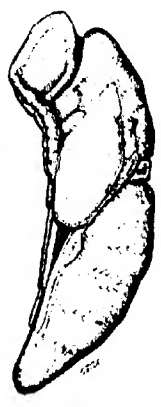


FIG. 8.—*Trimeromicrus maculatus*: Pupa

PUPA

The pupa (fig. 8) is white when newly formed. It is 1.6 mm. long and about 0.6 mm. wide. The head is placed slightly forward and the appendages are folded close to the body. The entire pupa is enclosed in a thin pupal skin. During the last few days of the pupal period the pupa turns almost black.

PUPATION.—The duration of the longest pupal period observed was 15 days and the shortest was 6 days. The average number of days in the pupa stage as observed in the laboratory was 9.

RELATIVE PROPORTION OF SEXES

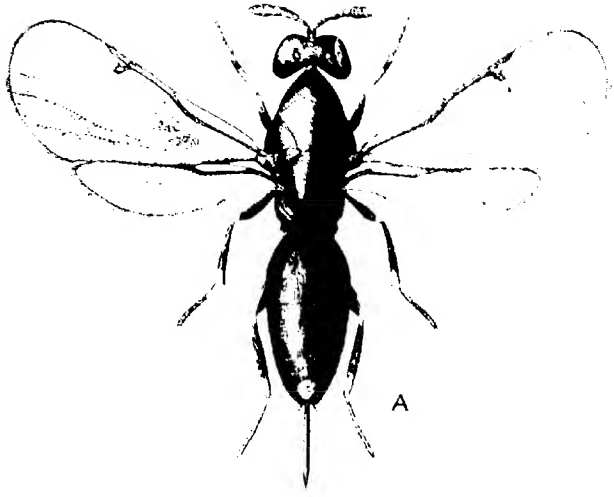
The localities from which this species was reared showed both sexes well represented. A count, made of 322 adults reared from various localities, showed 85 males and 237 females, or a ratio of 1 male to 2.67 females.

ECONOMIC IMPORTANCE

Trimeromicrus maculatus is apparently well established in the Yuma Valley of Arizona, where it was found to destroy about 7 per cent of the larvæ of *Bruchophagus funebris* infesting alfalfa seeds. Apparently it is also well established in the Honey Lake Valley of northeastern California.

PLATE 22

A.—*Liodontomerus perplexus*: Adult female.
B.—*Eutelus bruchophagi*: Adult female.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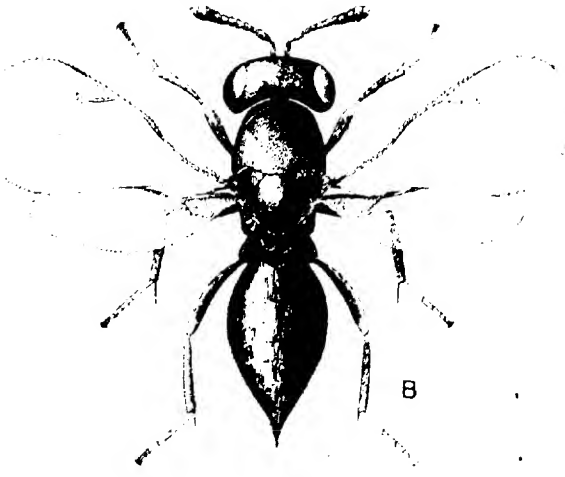
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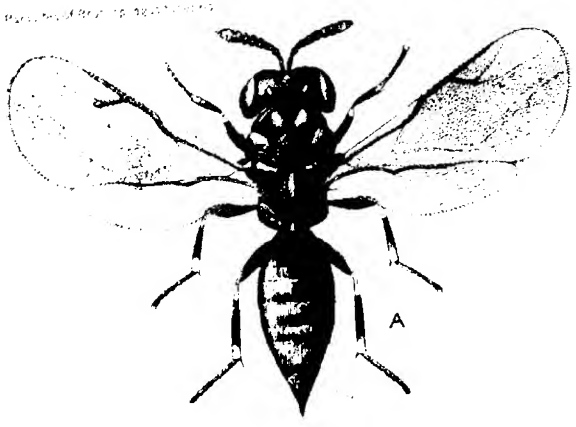
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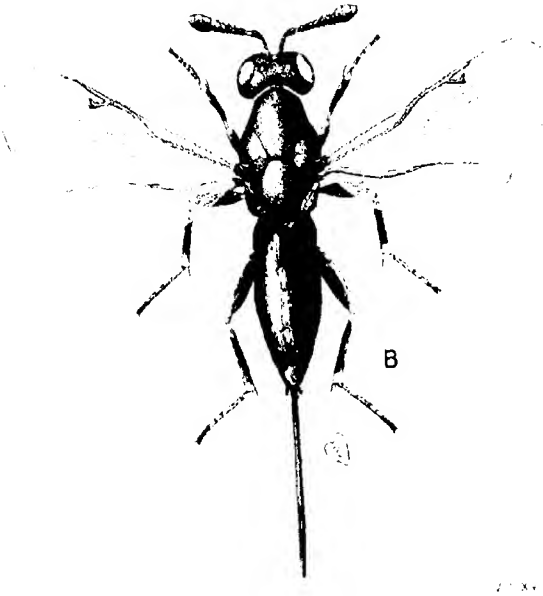
B

PLATE 23

A.—*Trimeromicrus maculatus*: Adult female.
B.—*Liodontomerus secundus*: Adult female.

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